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Materials Processing Using Miniature Low Voltage Electron Beam Guns

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Abstract

In the past several years, an increasing interest has developed in the low cost and low voltage (25 to 75 kilovolts) electron beam guns because of its capabilities in high-rate processing of thin-film polymer materials such as inks, adhesives and paints and sterilization of food packaging and medical supplies materials, etc. The key element of this technology is the thin film window that is relatively transparent to electrons and leak tight enough to maintain high vacuum for extended periods of time. This paper describes the performance of the thin-film windows and the low cost electron beam systems.

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Summary

For the last two decades wide area electron beams for commercial applications employed large metal vacuum vessels and titanium foil windows to allow the electron beam to exit from the vacuum into the atmosphere for processing applications. Typical current densities are 200 micro amperes per square cm. at voltages from 150 to 300 kilovolts. The minimum voltage of 150 kilovolts is significant because it is the energy required just to get the electrons through the metal foil. Such systems are very inefficient for the curing of coatings less than 40 microns thick (typical thicknesses for ink, paint or adhesive coatings) because more energy is deposited into the metal foil than the coating to be cured. The resultant electron beam systems cost millions of dollars primarily because of the x-ray shielding required and the associated cost of vacuum equipment and high voltage equipment. In spite of these relatively high costs, electron beam processing is a growing field. Many common products, such as floppy disks for computers, medical supplies, paints, inks and adhesives are processed using electron beams. A lower cost electron beam gun will not only be competitive in these existing applications, but will open up more applications through process cost benefits.

Lawrence Livermore National Laboratory and American International Technologies, Inc. have recently developed a low cost electron beam gun system capable of shooting electron beams several inches into the air for materials processing

applications. The key element of this technology is the thin film window that is relatively transparent to electrons and leak tight enough to maintain high vacuum for extended periods of time. Several contracts for developmental systems are currently in negotiation. These electron beam guns are unique in that they lower the cost of electron beam processing systems by one to two orders of magnitude compared to conventional electron beam equipment. Electron beam processing is a rapidly growing processing technology, driven by industry needs to avoid volatile organic compounds (VOCs) in ink, adhesive and paint curing. Additional applications include sterilization of food packaging and medical products by electron beam processing, which, with this low voltage electron beam system, are cost competitive processes. To the best of our knowledge, this patent pending approach is unique and has no competitor in the marketplace.

We have completed a series of tests to verify the performance of the thin-film windows and electron guns. Measurements include beam current, power, and power density, window transmission, temperature, and window endurance tests. A number of novel beam diagnostic tools were developed as part of this effort. Results show generally good agreement when compared to Monte Carlo computer predications. Transmitted beam powers in excess of 200 watts were achieved, with current densities exceeding 30 milliamperes per square centimeter at 60 kilovolts beam energy. Projected window wearout time exceeds several thousand hours at a current density of two milliamperes per square centimeters and a beam voltage of 60 kilovolts.

This paper is segmented into two major sections. The first section is a review of the status of the low voltage electron beam gun project at LLNL. The second section is a discussion of performance of the thin-film windows used in the low voltage electron beam gun systems.

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